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INVESTIGATION OF EFFECT OF INJECTION PRESSURE ON PERFORMANCE AND EMISSION CHARACTERISTICS OF COMPOSITE OIL BIODIESEL ON DI CI ENGINE

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ABSTRACT

The objective of the present investigation is to evaluate the Performance and Emission characteristics of Blends of methyl esters of composite oils(COme) of Karanja (PO) and Waste cooking oil(WCO)(B10, B20, B100) with Performance and Emission characteristics of methyl esters of Karanja oil(B100), methyl esters Waste cooking oil(B100) and diesel fuel at injection pressures of 160 bar, 180 bar and varying load conditions. The Transesterification process was carried out for composite oils of Karanja and Waste cooking oil (P50: W50), Karanja oil(PO), Waste cooking oil(WCO) and obtained biodiesel are blended with diesel in B10, B20, B100 for P50: W50 and B100 for individual oils of Karanja oil and Waste cooking oil. The Physico-chemical properties of biodiesel are presented and obtained as per ASTM standards. The effects of injection pressures, varying loads and blends of biodiesel with diesel on the Performance and Emission characteristics were evaluated using a Direct Injection (DI) Compression Ignition (CI) engine and tested at a constant engine speed of 1500 rpm. It was observed that there is an improvement in BTE (Brake Thermal Efficiency), while BSFC (Brake Specific Fuel Consumption) decreased when used with biodiesel blends in comparison with conventional diesel. The obtained results showed better Performance and Lower Emission of biodiesel from B20 of COme compared to biodiesel obtained from individual oils and diesel fuel and can be used without engine modification in a DI CI engine.

KEYWORDS: Transesterification, Composite Oil Biodiesel, Performance, Emission, Karanja Biodiesel,Waste Cooking Biodiesel & Diesel Engine

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Original Article

INTRODUCTION

Energy is a principal prerequisite for human existence. Consumption of fossil fuels has exceptionally expanded and the utilization of these energy assets has a major ecological effect. Diesel fuel, to a great extent, utilized as a part of transport, business, agriculture, domestic and modern divisions for the era of mechanical energy and power[1,2]. Out of all the substitute fuels accessible, bio-diesel procured from edible oils like Palm, rapeseed, Soybean, peanut, and sunflower oils suits well in biodiesel production, further even non-edible oils available like Cottonseed, Mahua, Jatropha and Karanja exhibit better properties in comparison to their edible oils counterparts. Availability and cost are the main factors for the choice of feedstock for biodiesel production and animal unsaturated fats guarantees to be more eco-accommodating at the point when contrasted with diesel fuel [3,4,5]. Notwithstanding, the cost of vegetable oils as of late has developed significantly, which will prompt higher

biodiesel generation costs. One method for decreasing the biodiesel generation costs is to utilize more affordable feedstock containing unsaturated fats like animal fats, squander nourishment oil, non-consumable oils and by-products of the refined vegetable oils[6]. Transesterification process was carried out by various researchers by varying catalyst (alkalis, enzymes, and acids), Reaction temperature, Methanol Concentration, Reaction time to produce biodiesel to meet the substitute fuel for diesel engines[7,8,9]. A lot of experiments have been carried out by researchers under varying operating conditions for different biodiesel produced from different feedstocks. Devan and Mahalakshmi [10] carried out experiments in order to study Combustion, Emission, and Performance characteristics of a Compression Ignition engine, operated by using blends of diesel and Methyl Ester of Paradise Oil (MEPS). The authors concluded that a reduction in the smoke and HC (Hydrocarbons) and by 40 % and 27% respectively. Simultaneously, they also observed an increase in oxides of nitrogen by 8%. Hoon Kiat Ng et al., [11] experiments with light-duty diesel engine depicted the Emission formation processes of biodiesel fuels and their combustion characteristics. Through a comparative study of baseline diesel fuel and soot from the combustion of biodiesel fuels such as coconut methyl ester (CME), formation mechanisms of nitrogen monoxide (NO_x), palm methyl ester (PME) and soybean methyl ester (SME) were studied. An increase in the degree of unsaturation in biodiesel fuels can have detrimental effects on soot concentrations and engine-out NO_x (oxides of nitrogen). Javier Campos-Fernandez et al., [12] carried out an intensive study on alternative types of fuels through in form of alcohols for internal combustion engines and the thrust was on the use of short chain alcohols, like methanol and ethanol, blended with fossil fuel. Authors have observed that the LHV (Lower Heating value) reduces due to the presence of the oxygen in the molecular structure of 1-pentanol and 1-butanol offsets, thus exhibiting better combustion and BTE. Observation depicts better diesel engine behavior by usage of higher alcohol blends as against that of lower alcohol blends usage. Although, they have opinioned that better performance pentanol properties for 30% Butanol/diesel fuel blend and 25% pentanol/diesel fuel blend may replace the use of 100% diesel fuel on diesel engines, Raouf Mobasheri et al., [13] observed that soot can be considerably reduced without NOx penalty rate by the process of injecting adequate fuel in post injection with an appropriate EGR (Exhaust Gas Recirculation). The conclusion drawn was that by combining multiple injections and EGR, a beneficial tool can be derived to control both soot emissions and NOx parallelly. Vivek Kumar Gaba et al., [14] developed a combustion model for diesel engine using biodiesel blends in the range of 20% to 100%. He concluded that for a pure diesel engine, the thermal efficiency decreases exponentially from 67% to 47% due to the increase in equivalence ratio from 0.7 to 1.3. As the equivalence ratio increased due to more fuel injection, two factors were observed. First one is a maximum temperature of the cycle approached to NOx formation temperature and the second one is an increase in work output was observed as the equivalence ratio increases due to more fuel injection. Mahanta et al.[16] concluded that 20% blending of Pongamia biodiesel has higher BSFC and BTE than mineral diesel at all engine loads. Reed et al. [17] Performance test carried out in diesel engine and the results obtained for waste cooking oil methyl esters and diesel fuel was in good agreement. Suryawanshi et al.[18] experimented using blends of Pongamia methyl ester with diesel fuel and found a reduction in HC and CO (Carbon Monoxide) emissions at part loads as well as full load compared to diesel fuel. Grimaldi et al.[19] concluded that BTE was found higher in blends of biodiesel compared to diesel fuel at high loads in a diesel engine. Xiangmei et al. [20] did an experiment using diesel engine without any modification by comparing results of diesel fuel and biodiesel fuel usage. The results exhibited that HC, CO emissions reduced from 20% to 18% in comparison with diesel fuel. Jain et al. [21] performed an experiment in a diesel engine using methyl esters of Waste cooking oil and its blends with diesel. The results showed that for 100% biodiesel BSFC was 17.8 % higher than diesel at 100% load while BTE results depicted almost similar results of diesel fuel. The review results infer that methyl esters of Karanja and Waste fry oil can be used as other options of fuels in diesel engines.

In the present work, the main aim of the investigation is to evaluate the Performance and Emission characteristics of blends of COme(B10,B20,B100) with Performance and Emission characteristics of POme(B100), WCOme(B100) with diesel fuel at 2 injection pressures of 160 bar and 180 bar at varying load conditions. The COme, individual oils of PO and WCO were converted into biodiesel and Physico-Chemical properties were investigated and tabulated in Table 1. The properties were determined for diesel, POme (B100), WOme(B100) and COme with B10, B20, B100 blends. The properties obtained were within the limits of ASTM standards. The effect of 2 injection pressures at 160 bar and 180 bar, varying load condition of 0%.25%,50%,75%,100% on COme were compared with the POme, WCOme with diesel fuel on Performance and Emission parameters are discussed. The Performance parameters such as Brake thermal efficiency (BTE), Brake Specific Fuel Consumption (BSFC) and Emission parameters such as CO, CO_2, HC, NO_x are discussed. The results showed that the COme gave the best Performance, lower Emissions when compared to individual oils of POme, WCOme and can be used as alternative fuel.

MATERIALS AND METHODS

Production of Biofuel and its Properties

Karanja oil popularly known as Pongamia oil extracted from seeds of Pongamia pinnata tree were collected from Bannari Sugar mills Pvt limited, Coimbatore and used Waste cooking oil collected from a Bangalore hotel. The transesterification process was carried out for CO, PO and WCO to produce biodiesel. The Fatty acid content present in the Composite oil(CO), Karanja oil(PO), Waste Cooking oil(WCO) were removed by 2 step transesterification process(Figure 1). In the first step, acid was used for converting fatty acids into methyl esters of vegetable oils and Methanol (6:1 molar ratio), Sulphuric acid (1% of oil) and then in the second step base Catalyzed Transesterification was done using Sodium Hydroxide(NaOH) (1% of oil) in order to produce methyl esters with reaction time of 90 minutes and reaction temperature of 65^0C and stirred at 500 rpm [6,7,21]. The COme,POme,WCOme were produced in transesterification set up. COme(B100,B10.B20), POme (B100), WCOme(B100) were used to test the Performance and Emission parameters by blending with diesel and comparing the results with that of diesel fuel. A Kirloskar AV-1, single cylinder CI DI engine was used for the experimentation and Eco gas-4 analyzer was used for emission test.

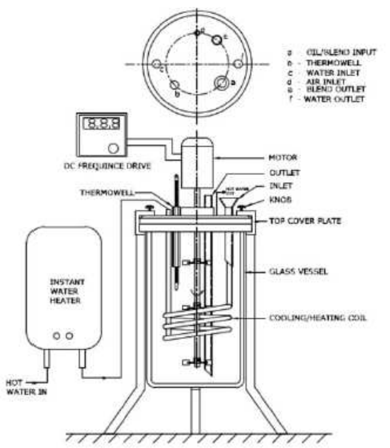


Figure 1:Transesterification Set Up

Figure 2:Engine Setup

Table1: Properties of Biodiesel

Properties	Methyl esters of Karanja (POme)oil(B 100)	Methyl esters of Waste Cooking oil(WCOme) (B100)	Commercial Diesel	COme B10	COme B20	COme B100	ASTM standards
Density(kg/m$^{3)}$	870	868	832	844	850	861	860-900
Kinematic viscosity at 40^{0}C(cSt)	4.56	4.32	2.78	3.94	4.10	4.41	2.5-6.0
Flash Point (^{0}C)	146	150	92	123	132	137	120
Specific Gravity	0.850	0.838	0.832	0.844	0.850	0.861	0.86-0.90
Fire Point ^{0}C	166	170	102	143	151	152	Not mentioned
Calorific Value(kJ/kg)	38900	38100	47800	41900	41000	39000	Not Mentioned
Cetane Number	52	59	49	51.10	51.60	52.92	Not Mentioned

EXPERIMENTATION METHODOLOGY

The Engine employed was a single cylinder four stroke Compression Ignition Direct Injection engine at varying loads of 0%, 25%, 50%, 75% and 100% for B100 for COme, POme, WCOme and B10, B20 for COme. At the first stage, the engine was run using diesel fuel and Performance parameters and Emission parameters were noted for each load. Similarly, biodiesels of various proportions were used and results were noted down. The engine (Figure 2) was loaded with lamp loading equipment switch by keeping the field intensity knob at the maximum position and the load was measured using a load cell and torque arm. The digital torque indicated the value of torque and it was connected to the computer (Figure 3). The procedure was carried out for injection pressures of 160 bar and 180 bar. The specifications of the engine are as shown in Table 2.

RESULTS AND DISCUSSIONS

Brake Specific Fuel Consumption (BSFC), Brake thermal efficiency(BTE) are the Performance characteristics and Emission Characteristics such as CO,CO_2,HC,NO_x recorded for blends of B10, B20 and B100 of COme, B100 of POme,WCOme and neat diesel fuel. The results show similar trends as that of neat diesel fuel.

Brake Specific Fuel Consumption (BSFC)

The figures 4 and 5 depict the variation of BSFC, with varying loads(0%,25%,50%,75%, 100%)at injection pressures of 160 bar and 180 bar for blends of COme (B10,B20,B100) and POme (B100) and WCOme (B100). The BSFC for B10 is 0.25kg/kW-hr,B20 is 0.24 kg/kW-hr, B100 is 0.29 kg/kW-hr for COme at 160 bar injection pressure at full load condition and

Table 2: Engine Specification

Make	Kirloskar AV-1
Bore	80mm
Stroke	110mm
Number of cylinders	1
Compression Ratio	1:17.5
Capacity	3.5kW

Table 2: Contd.,	
Mode of injection	Direct injection
Engine speed	1500rpm
Cooling Method	Water cooled
Pressure	180bar

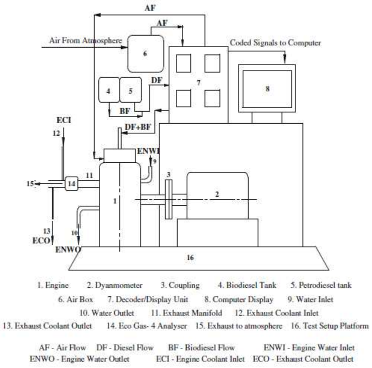


Figure.3: Line Diagram Engine Set up

for B10 is 0.24 kg/kw-hr,B20 is 0.23 kg/kw-hr,B100 is 0.28 kg/kW-hr at 180 bar for COme at full load condition. BSFC for B100 of POme is 0.29 kg/kW-hr,WCOme(B100) is 0.28kg/kW-hr at 160 bar at full load condition and BSFC for B100 of POme is 0.27 kg/kW-hr, WCOme (B100) is 0.26kg/kW-hr at 180 bar at full engine loads. The BSFC values exhibited by diesel fuel is 0.27kg/kW-hr and 0.26kg/kW-hr at 160 bar and 180 bar respectively. The BSFC values exhibited by the blends of COme were lower than those of the diesel fuels. At a higher injection pressure of 180bar, the BSFC decreased due to improved combustion, as the atomization improved at part load and full load condition. BSFC for COme showed the lower value compared to diesel fuel, POme and WCOme. For B20 blend for COme, 11.53% improvement over conventional diesel fuel. Tilak.et.al., [6] carried out experiments on biodiesel derived from composite oil of Jatropha-waste cooking oil and observed that BSFC decreased by 17.1% over diesel as reported by many researchers[27 to 30].Varatharu et.al.,[22] observed that BSFC increases by 5% over conventional diesel for Pongamia biodiesel for blend B20.S.Mohite et.al.,[23] observed that there is a decrease in BSFC, as an increase in load due to lower heating value.B.Tesfa et.al., [25]concluded that, BSFC lowered for diesel compared to bio-diesel.Zhu et.al.,[31] reported that BSFC of Waste cooking biodiesel decreased from 570g/kW-hr to 240g/kW-hr as the Brake Mean Effective Pressure improved from 0.08 Mpa to 0.7 Mpa.

Brake Thermal Efficiency

The Figures 6 and 7 depict the variation of BTE with various loads(0%,25%,50%,75%, 100%) at injection pressure of 160 bar and 180 bar of B10,B20 for COme and B100 for COme,POme and WCOme. The BTE for B10 is 33.9%, B20 is 34.2%, B100 is 29.8% for COme at 160 bar injection pressure and The BTE for B10 is 34.2%, B20 is 37.7%, B100 is 31% for COme at 180 bar. BTE for POme(B100) is 29%,WCOme(B100)is 28.6% at 160 bar injection pressure and POme(B100) for 30.6%,

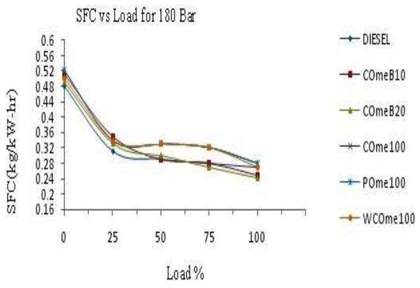


Figure.4: Variations of SFC with Load

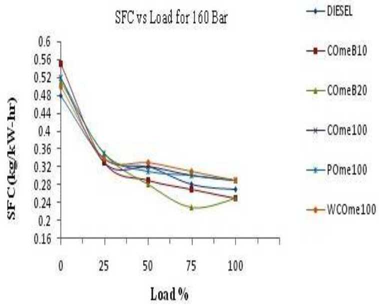


Figure 5: Variations of SFC with Load

WCOme(B100) is 30.2% at 180bar,similarly for diesel fuel is 31.4% at 160 bar injection pressure and 32.3% at 180bar injection pressure at full engine loads. The BTE values exhibited by the blends of COme were higher than those of the diesel fuels, POme and WCOme. At lower injection pressure of 160bar, the BTE decreased due to poor atomization and spray formation. As the pressure increased to 180 bar, the BTE increased as the ignition delay period decreased due to improved combustion and atomization. BTE for B20 blend of COme is 14.32% improved over conventional diesel fuel. BTE incremented with an increase in load due to heat loss reduction and Brake Power incremented as we increase the load due to the higher viscosity of biodiesel because of fuel droplets grow in size during the atomization [15]. Mahantha et.al., [16] concluded that BTE for B15 and B20 incremented throughout the complete range of loading due to oxygen present in the Pongamia biodiesel. Varatharaju et.al [22] experimented on biodiesel with Pongamia shows similar values that BTE decreases with increased percentage of biodiesel blends and observed that 2.4% decreased BTE over conventional diesel for B20. S.Mohite et.al., [23] experimented on mixed oils and concluded that BTE for Diesel is 29.72% while for B10, B30 is 28.76,27.92 respectively that is BTE decreased over diesel. B.Tesfa et.al.,[24] concluded that diesel and biodiesel exhibited similar BTE i.e., 35%.Bhupendra et.al.,[25] reported that BTE for Pongamia biodiesel decremented compared to diesel(27%).Avinash et.al., [26] depicted that Karanja Biodiesel for blend B10 exhibited similar results compared to diesel.

Carbon Monoxide(CO)

The Figures 8 and 9 depict the variation of CO with various loads(0%,25%,50%,75%,100%) at injection pressures of 160 bar and 180 bar of B10,B20 for COme and B100 for COme,POme and WCOme. The CO for B10 is 0.0419%,B20 is 0.0385%,B100 is 0.046% for COme at 160 bar injection pressure and for B10 is 0.038%,B20 is 0.0365%,B100 is 0.043% for COme at 180 bar injection pressure.CO for POme(B100) is 0.0476%, WCOme(B100) is 0.0486% at 160 bar injection pressure and POme(B100) is 0.047%,WCOme(B100) is 0.0475 % at 180 bar injection pressure, similarly CO for diesel fuel is 0.053% at 160 bar injection pressure and 0.048% at 180 bar injection pressure at full engine loads. The CO values exhibited by the blends of COme were lower than those of the diesel fuels, POme and WCOme[32]. At lower injection pressure of 160bar, the CO emissions increased due to improper combustion, stoichiometric ratio. Compared to diesel fuel, the B20 blend of COme at 180bar injection pressure CO emission has reduced by 19.79%.

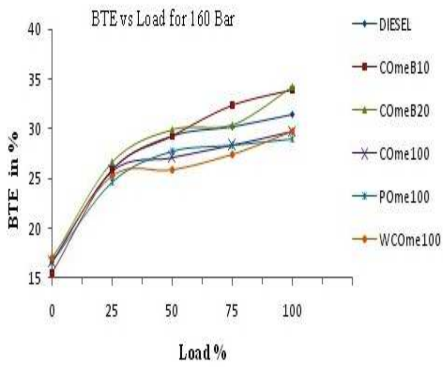


Figure 6: Variations of BTE with Load

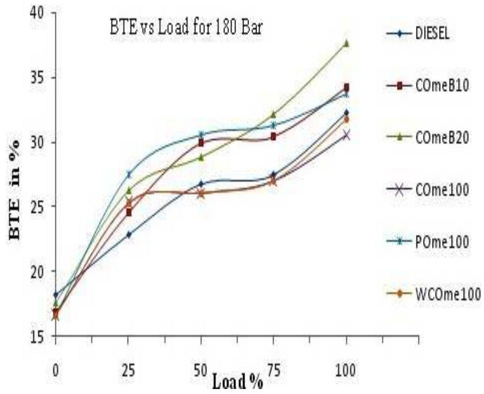


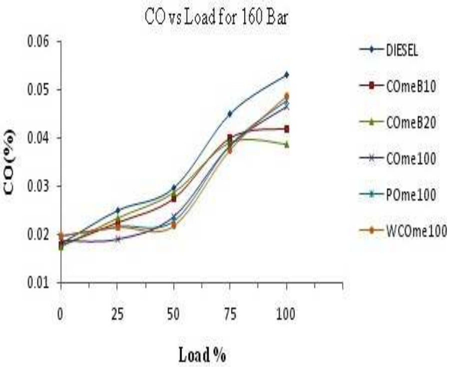
Figure 7: Variations of BTE with Load

Hydrocarbons (HC)

The Figures 10 and 11 depict the variation of Hydrocarbons in ppm with various loads(0%,25%,50%,75%,100%)at injection pressures of 160 bar and 180 bar of B10,B20 for COme and B100 for COme, POme and WCOme. The HC for B10 is 17 ppm, B20 is 16.5 ppm, B100 is 19 ppm for COme at 160 bar injection pressure and for B10 is 16 ppm, B20 is 15.5 ppm, B100 is 17 ppm for COme at 180 bar injection pressure. HC for POme (B100) is 20 ppm WCOme(B100) is 19.5 ppm at 160 bar injection pressure and POme(B100) is 18 ppm WCOme(B100) is 19 ppm at 180 bar injection pressure, similarly HC for diesel fuel is 24 ppm at 160 bar injection pressure and 22 ppm at 180 bar injection pressure at full engine loads. The HC values exhibited by the blends of COme were lower than those of the diesel fuels, POme and WCOme. For all blends B10, B20, B100 compared to diesel due to the presence of rich mixture in biodiesel results in increased flame propagation rate, improved combustion consequently reduces the ignition delay increases the reaction rate results in lesser amount of Hydrocarbons. The B20 blend of COme at 180 bar injection pressure has 29.5% reduced over diesel.

Oxides of Nitrogen(NO_x)

The Figures 12 and 13 depict the variation of oxides of Nitrogen in ppm with various loads(0%,25%,50%,75%,100%) at injection pressures of 160 bar and 180 bar of B10,B20 for COme and B100 for COme,POme and WCOme. The NO_x (ppm) for B10 is 227 ppm, B20 is 236 ppm, B100 is 279 ppm for COme at 160 bar injection pressure and for B10 is 237 ppm, B20 is 245 ppm, B100 is 279 ppm for COme at 180 bar injection pressure. NO_x (ppm) for POme(B100) is 276 ppm, WCOme(B100) is 275 ppm at 160 bar injection pressure and POme(B100) is 286 ppm, WCOme(B100) is 284 ppm at 180 bar injection pressure, similarly NO_x (ppm) for diesel fuel is 218ppm at 160 bar injection pressure and 225 ppm at 180 bar injection pressure at full engine loads. The NO_x (ppm) emissions increased with the increasing engine load. This was due to a reduction in heat loss and increase in power with an increase in load and hence the in-cylinder temperature. The most important factor for the emissions of NO_x (ppm) is the combustion temperature in the engine cylinder. It can be seen from the figures 12 and 13 that



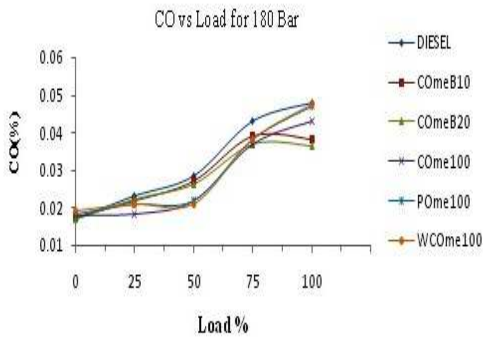
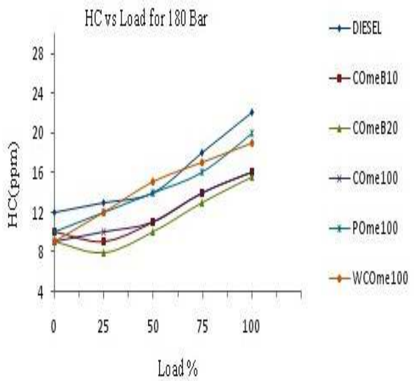


Figure 8: Variations of CO(%) with Load **Figure 9: Variations of CO(%) with Load**



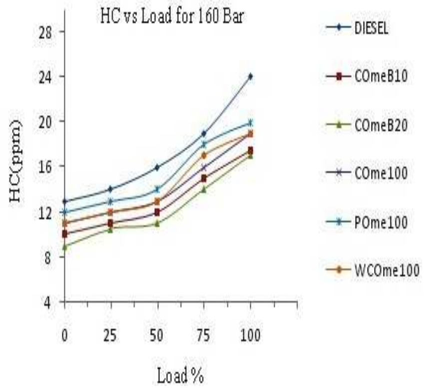
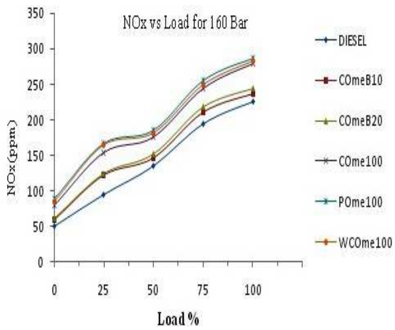


Figure.10: Variations of HC vs Load **Figure.11: Variations of HC with Load**

NO_x (ppm) emissions from the biodiesel blends is found to be high when compared to that of diesel fuel. The NO_x (ppm) values exhibited by the biodiesel blends were higher than those of the diesel fuels. The B20 blend of COme at 180 bar injection pressure has 19.7% increased NO_x (ppm) emission in comparison with diesel.



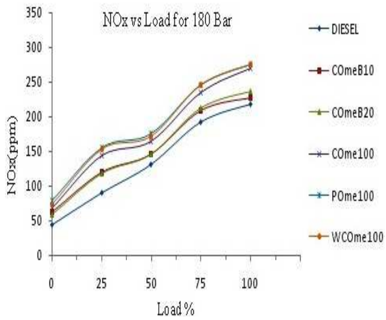
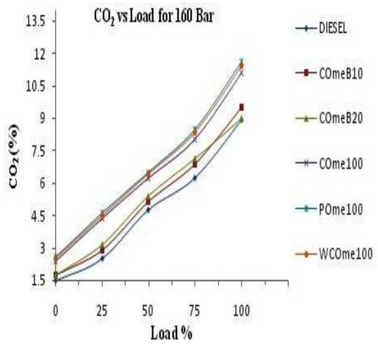


Figure.12: Variations of NOx with Load **Figure.13: Variations of NOx with Load**

CO_2(Carbon dioxide)

The Figures 14 and 15 depict the variation of CO_2 with various loads(0%,25%,50%,75%,100%) at injection pressures of 160 bar and 180 bar of B10,B20,B100 for COme and B100 for POme and WCOme. The CO_2 for B10 is 9.52%, B20 is 8.7%,B100 is 11.1% for COme at 160 bar injection pressure and for B10 is 9%, B20 is 8.33%,B100 is 10.6% for COme at 180 bar injection pressure. CO_2 for POme (B100) is 11.6%, WCOme (B100) is 11.4% at 160 bar injection pressure and POme(B100) is 10.9%,WCOme(B100) is 11% at 180 bar injection pressure, similarly CO_2 for diesel

fuel is 8.9% at 160 bar injection pressure and 8.5% at 180 bar injection pressure at full engine loads. The CO_2 values exhibited by the blends of COme were slightly lower than that of the diesel fuels, POme and WCOme. At lower injection pressure of 160bar, the CO_2 emissions increased due to improper combustion, stoichiometric ratio. Compared to diesel fuel, the B20 blend of COme at 180bar injection pressure has 2% reduction in CO_2 emission.



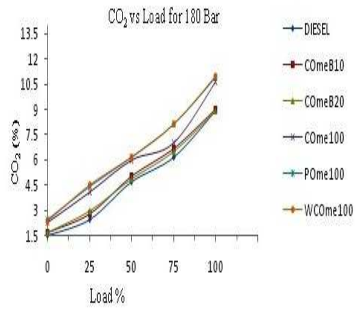


Figure 14: Variations of CO_2 with Load **Figure 15: Variations of CO_2 with Load**

CONCLUSIONS

Experiments have been carried out in the present study using DI CI engine of 3.5 kW by varying injection pressures (160 bar and 180 bar) and varying loads in order to evaluate the Performance and Emission characteristics using COme and comparison with POme, WCOme and Conventional diesel. The following conclusions have been made:

- The properties of biodiesel are within the limits of ASTM standards and are comparable to diesel fuel after transesterification process.
- Brake Specific Fuel Consumption for B20 blend of COme has 11.53% reduction in comparison with conventional diesel fuel.
- Increase in injection pressure from 160 bar to 180 bar, increases the BTE. BTE For B20 blend of COme is a 14.32 % improvement over conventional diesel fuel at 180 bar.
- Emissions such as CO, CO_2, HC of COme have decreased, when compared to diesel fuel by 19.79%,2%,29.5% respectively, but in case of NO_x (ppm), it increased by 19.7%.
- Thus, we can optimize for 180 bar of injection pressure and blend B20 of COme as it has given a superior Performance and lower Emission characteristics over conventional diesel fuel, POme, WCOme.

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Nomenclature

COme	Composite oil methyl esters
B10	90%of diesel and 10% of biodiesel
B20	80% of diesel and 20% of biodiesel
B100	100% of biodiesel
Pome	Karanja oil methyl ester
WCOme	waste cooking oil methyl esters